Evolution and distribution of the reductive tricarboxylic acid cycle for autotrophic carbon fixation in extremophilic microorganisms

Michael Hügler
Biology Department
Woods Hole Oceanographic Institution
Woods Hole, MA, 02543
USA
mhugler@whoi.edu

Stefan M. Sievert
Biology Department
Woods Hole Oceanographic Institution
Woods Hole, MA, 02543
USA
ssievert@whoi.edu

Chemolithoautotrophic organisms play an essential role in ecosystems by providing a continuous supply of organic carbon for heterotrophs. They are likely to be one of the earliest organisms that evolved on Earth, making the study of extant chemolithoautotrophs intriguing in the context of the origin and "Early Evolution of Life". Besides the Calvin cycle, there are three carbon fixation pathways known: the reductive acetyl-CoA pathway, the reductive tricarboxylic acid cycle (rTCA) and the 3-hydroxypropionate cycle. Many consider the rTCA cycle to be the most ancient autotrophic carbon fixation pathway, possibly also present in microorganisms that might exist on other planetary bodies with reducing environments. We are examining the occurrence of the rTCA cycle in various autotrophic and extremophilic microorganisms whose growth requirements fit well with the likely conditions on primitive Earth. We measured enzyme activities and amplified and sequenced the genes coding for ATP citrate lyase (ACL), a key enzyme of this pathway. The sequence data are used to explore phylogenetic patterns generated by ACL for insights into the evolution of this pathway and its environmental significance. The data support the view of the rTCA as an ancient metabolic pathway from which other pathways could have evolved. Furthermore the data indicate that the rTCA might be more common for carbon fixation than previously thought and that organisms utilizing this pathway are likely to contribute significantly to biomass production at various extreme habitats, like submarine hydrothermal vents, oxic/anoxic interfaces, and the subsurface.